CERN
CH-1211 Geneva 23
Switzerland

the **Large Hadron Collider** project

LHC Project Document No.
LHC-TT-ES-0001.00 rev 0.2
CERN Div./Group or Supplier/Contractor Document No.
AB-OP TS-LEA
EDMS Document No.

Date: 2005-08-18

Functional Specification

LHC EXPERIMENTS BEAM INTERLOCKING

Abstract

This document describes the beam interlocking of the LHC experiments. Two different types of interlocks are discussed: beam dump requests and injection inhibits. The interlocking strategy for movable devices is defined. Furthermore a number of software signals are defined to facilitate automatic preparation of the experiments for procedures that represent an increased risk of beam loss and for controlled beam dumps at the end of fills.

Prepared by :	*Checked by :*	*Approved by*
D. Macina TS/LEA Daniela.Macina@cern.ch **W. H. Smith PH/UCM** wsmith@hep.wisc.edu **J. Wenninger AB/OP** Jorg.Wenninger@cern.ch	**R. W. Assmann AB/BDI** **R. Bailey AB/OP** **N. Ellis PH/ATR** **D. Evans PH/UAI** **P. Grafstrom PH/ATI** **R. Jacobsson PH/LBC** **M. Lamont AB/OP** **M. Oriunno PH/TOT** **K. Potter TS/HDO** **B. Puccio AB/CO** **E. Sbrissa PH/DT1** **R. Schmidt AB/CO** **A. Smith PH/LBD** **E. Tsesmelis TS/LEA**	**A. Ball PH/CMM** **C. Fabjan PH/AIO** **A. Herve PH/CMO** **L. Leistam PH/AIS** **S. Myers AB** **M. Nessi PH/ATO** **E. Radermacher PH/TOT** **W. Witzeling PH/LBO**

Approval List:

P. Collier, B. Dehning, M. Ferro-Luzzi, B. Frammery, M. Gallio, B. Goddard, R. Lauckner, R. Losito, A. Morsch, H. Schmickler, B. Todd

Hardware interlock for the experiments

- All LHC experiments hardware interlocks NON-MASKABLE
  - In the production of the non-maskable signal, the experiments will apply their own masks internally (information on the beam intensity and energy may be used). However, the signal cannot be masked by the machine since only the experiments themselves are able to evaluate the risk of masking some channels from their detectors
  - The non-maskable interlock signals must be operational and fully reliable already during the LHC machine checkout period

- Each experiment can provide up to 3 different hardware interlock signals:
  - Injection inhibit (directly to the injection system)
  - Beam dump request (to BIC)
  - Position interlocks from movable devices (to BIC)

Injection inhibit

- Experiments have asked the possibility to inhibit injection without dumping the beam :
  - The injection inhibit is based on the state of the detectors and does not depend on data from radiation monitors (apart from the requirement that the radiation monitors are operational)
  - It indicates that the detectors are not in a safe state to cope with comparatively high backgrounds that will occur during injection (and ramp). In other words, it is there to minimize the risk of damage to the detector.
  - Should one of the injection interlock become FALSE during injection, it is not so clear (from the experiment point of view) if beam already circulating should be dumped
  - Injection will also be inhibit after a dump has been triggered (by the same experiment) pending assessment of the causes of the dump
- This implies the realisation of the injection interlock system: budget and manpower to realise the system needs to be discussed as soon as possible to have it ready for the LHC start-up

Beam dump request

- The experiment dump request is based on data from the radiation monitors that, combined by the experiment with the state of the detector, indicates that there is an immediate danger of damage to the detector
- Beam dump will be done in a fail-safe system

Interlocking of movable devices Roman Pots and VELO

- This special interlock is related ONLY to the position of the movable devices since their position (between 10-70 σ) may directly interfere with beam operation. Interlocks related to the system housed in the pots or in VELO and to the radiation monitors go with the injection inhibit and beam dump signal
- End-switch defines the garage position
- The interlock signal is fed into the BIC and it becomes FALSE when the garage position is left unless the machine mode is in:
  - STABLE BEAM (to allow data taking)
  - UNSTABLE BEAM (to allow the operator to intervene on the beam as soon as possible (if necessary) without waiting for VELO and Roman Pots being in their garage position (it may take some minutes)). Of course, the operator should keep in mind that VELO and/or Roman pots are not in the safe position
  - If the conditions degrade slowly, the operator should go to ADJUST mode and wait until Roman Pots and VELO are in the garage position (if not a beam dump will be triggered)

Interlocking of movable devices
ZDC

- The ZDC can move in the vertical plane and its data taking position is at the beam plane. However, it will be lowered down:
  - at injection to protect it from injection errors
  - whenever data taking is not needed to reduce the absorbed dose
- The ZDC does not interfere with the beam since it is located outside the vacuum chamber. Therefore, from the machine protection point of view is no issue (unless it does not damage the vacuum chamber located at a few mm..)
- The interlock is only need to protect the ZDC
- Only an injection inhibit on beam1 is foreseen if the ZDC is not in the garage position (end-switch)
- No dump trigger is connected to the position of the ZDC

Interlocking of the experiment spectrometer magnets

- Only the dipole magnets have a large effect on the beam (they are part of the crossing scheme at IP2 and IP8). However, time constant are not critical (beam moves by 1 σ in several hundreds milliseconds)
- Nevertheless all dipoles, toroids and solenoids will be interlocked
- In case of magnet fault, the signal must be sent to the machine interlock 10 ms before the magnet power converter switchs off
- There will be one signal per experiment (4 signals in total)
- However, it looks like not all the Magnet Project Leaders are aware of these interlocks. We should clarify this question before we release the version for the final approval

Special signals:
Ready for increased risk procedure

- Software signals provided over the DIP data exchange
- Each experiment will provide a READY-FOR-INCREASED-RISK-PROCEDURE signal = TRUE for the operator to start increased-risk procedures that go beyond the typical tuning to maintain beam conditions
- The signal is an acknowledge in response to the INCREASED-RISK-PROCEDURE –REQUEST signal from the machine
- Once the READY-FOR-INCREASED-RISK-PROCEDURE is received, the operator will change the machine mode from STABLE BEAMS to ADJUST
- A time-out will be introduced: if no acknowledge is received, the operator will change the mode to UNSTABLE BEAM and take action (ADJUST will trigger a dump if the movable devices are not in the garage position)

Special signals: Ready for beam dump

- Software signals provided over the DIP data exchange
- Each experiment will provide a READY-FOR-BEAM-DUMP signal required to be true to abort the beam in a controlled way at the end of the fill
- It is an acknowledgement in response to an IMMINENT-BEAM-DUMP signal from the machine
- It indicates that whatever steps should be taken by the experiments to minimize damage during machine abort have been taken

Summary and future steps

- All the functionalities of the BIS with respect to the experiments have been defined
- No major comments to the Engineering Check
- Magnet interlock should be checked with the experiments before we go for the final approval
- The injection interlock system should be discussed as soon as possible
- Technical specifications will follow